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THE NEARBY YOUNG VISUAL BINARY HIP 115147 AND ITS COMMON PROPER MOTION COMPANION LSPM J2322+7847

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ABSTRACT

We report a late M-type, common proper motion companion to a nearby young visual binary HIP 115147 (V368 Cep), separated by 963″ from the primary K0 dwarf. This optically dim star was identified as a candidate high proper motion, nearby dwarf LSPM J2322+7847 by Lépine in 2005. The wide companion is one of the latest post–T Tauri low-mass stars found within 20 pc. We obtain a trigonometric parallax of 51.6 ± 0.8 mas, in good agreement with the *Hipparcos* parallax of the primary star (50.7 ± 0.6 mas). Our *BVRI* photometric data and near-infrared data from 2MASS are consistent with LSPM J2322+7847 being brighter by 1 mag in K_s than field M dwarfs at $V - K_s = 6.66$, which indicates its pre–main-sequence status. We conclude that the most likely age of the primary HIP 115147 and its 11″ companion HIP 115147B is 20–50 Myr. The primary appears to be older than its close analog PZ Tel (age 12–20 Myr) and members of the TWA association (7 Myr).

Subject headings: astrometry — binaries: visual — stars: individual (HIP 115147, LSPM J2322+7847) — stars: pre–main-sequence

1. INTRODUCTION

In the course of an extensive search for very wide, common proper motion companions to nearby *Hipparcos* stars from the NOMAD catalog (Zacharias et al. 2004), we came across an optically faint and red star at an angular separation of 963″, position angle 141° from the active and rapidly rotating G9 V star HIP 115147 (BD +78 826, HD 220140, V368 Cep). This faint star was subsequently identified with LSPM J2322+7847, a candidate nearby low-mass dwarf detected by Lépine (2005) from the LSPM-North catalog (Lépine & Shara 2005). The original identification of this star as one with significant proper motion traces to Luyten (1969), where it was reported as a magnitude 17 object with $\mu = 200$ mas yr^{-1} at a position angle of 67° and assigned the name LP12-90.

In this Letter we present new *BVRI* photometry of HIP 115147, its known visual companions HIP 115147B and LSPM J2322+7847, and obtain preliminary trigonometric parallax astrometry for the latter companion. Then we discuss the possible young age and origin of this interesting triple system.

2. OBSERVATIONS

Following the identification of LSPM J2322+7847 as a potential widely separated common proper motion companion to HIP 115147, *BVRI* photometry on the Cousins system was obtained for the fainter star on 2005 August 30 UT using the 1.0 m reflector at the Flagstaff Station. The photometry was calibrated with an instrumental zero-point term and a first-order air-mass term. The calibration field was the standard field PG 2213-006 from Landolt (1992). Additional photometric observations were subsequently obtained on 2007 June 16 and 17 UT when the individual components of the brighter system HIP 115147AB (separation 11″) were also measured. The photometric results are presented in Table 1 along with *JHK* photometry extracted from 2MASS, proper motions from NOMAD, and parallax determinations. The estimated uncertainties in the *BVRI* measures are ±0.02 mag in the case of LSPM J2322+7847 and ±0.03–0.04 mag for the HIP 115147 components, where the short exposure times introduced additional error from scintillation and shutter timing.

Since the 2005 August photometry indicated that LSPM J2322+7847 was most likely an M-dwarf at approximately the same distance as HIP 115147, it was added to the trigonometric parallax program at USNO's Flagstaff Station. Through 2007 June, a total of 66 acceptable CCD observations have been accumulated on this field, covering an epoch range of 1.65 yr. The same Tek2k CCD, observational procedures, and reduction algorithms have been employed as summarized in Dahn et al. (2002). Using a total of 29 reference stars, the current preliminary solution yields $\Pi_{\rm rel} = 50.72 \pm 0.73$ mas. This solution appears to be very robust, with the separate solutions for parallax in the R.A. and decl. directions in very satisfactory agreement (50.72 ± 0.77 mas vs. 50.69 ± 2.30 mas, respectively). Correction to absolute parallax was performed using USNO *BVI* photometry for the individual reference stars along with a calibrated M_V versus $V - I$ relationship to derive a mean photometric parallax of 0.85 ± 0.15 mas for the 29 star ensemble. Together this then translates to $\Pi_{\rm abs} = 51.6 \pm 0.8$ mas for LSPM J2322+7847.

3. ACTIVITY AND AGES

The star HIP 115147 was identified with the bright X-ray source H2311+77, which led Pravdo et al. (1985) to suggest RS CVn–type activity. It was shown later on that the star is not evolved, and that it is not a short-period spectroscopic binary, justifying the currently accepted classification as a very young, "naked" post–T Tauri dwarf (Nations et al. 1990; Chugainov et al. 1991, 1993). Being one of the most powerful X-ray emitters in the solar neighborhood (Voges et al. 1999) at $L_{\rm X} = 1.04 \times 10^{30}$ ergs s^{-1} (Makarov 2003), the star has the

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TABLE 1
ASTROMETRY AND PHOTOMETRY OF HIP 115147 A, B, AND LSPM J2322+7847

Name	HIP 115147 A	HIP 115147 B	LSPM J2322+7847
R.A. (J2000.0)…	23 19 26.632	23 19 24.53	23 22 53.873
Decl. (J2000.0)…	+79 00 12.67	+79 00 03.8	+78 47 38.81
Π …	50.7 ± 0.6		51.6 ± 0.8
Proper motion…	(201, 72) ± (1, 1)	(203, 72)	(210, 64) ± (2, 3)
B…	8.60	13.75	17.99
V…	7.73	12.24	16.16
R…	7.17	11.04	14.61
I…	6.76	9.54	12.54
J…	5.90	8.04	10.42
H…	5.51	7.39	9.84
K_s…	5.40	7.20	9.52

NOTES.—Units of right ascension are hours, minutes, and seconds, units of declination are degrees, arcminutes, and arcseconds, proper motion is in units of mas yr^{-1}, and parallax is in mas. Parallax for HIP 115147 A is from *Hipparcos*, parallax for LSPM J2322+7847 is our observation. Proper motion for HIP 115147 A is from *Hipparcos*, for HIP 115147 B from (Gould & Chanamé 2004), and for LSPM J2322+7847 from NOMAD. *BVRI* magnitudes are our measurements. JHK_s magnitudes are from 2MASS. The relative position of the faint companion at J2000 is separation 962.56″, position angle 141.1°.

same space velocity as the Local Young Stream (or Local Association; Montes et al. 2001). This association limits its age to ≲200 Myr. This stream includes isolated stars, groups, and associations of diverse ages, some as young as 1 Myr (e.g., in Lupus and Ophiuchus). Therefore, the assignment to this stream by itself does not lend a more precise estimation of age. An X-ray luminosity of $\log L_X \approx 30$ is typical of weak-lined TT stars in Taurus-Auriga-Perseus, but significantly larger than that of classical TT stars; if anything, it points at an age older than a few Myr. HIP 115147 is listed as variable star V368 Cep (Kholopov et al. 1989). The slight variability allowed Kahanpää et al. (1999) to determine the period of rotation of this star, 2.74 days. The fast rotation is responsible for the high degree of chromospheric and coronal activity. The primary star is identified as the extreme ultraviolet source EUVE J2319+790 with strong detections at the 100 Å band, as well as at 250 eV in X-rays (Bower et al. 1996; Lampton et al. 1997). HIP 115147 is one of the 181 extreme-ultraviolet sources in the *ROSAT* WFC all-sky bright source survey identified with late-type main-sequence stars (Pounds et al. 1993), with high signal-to-noise ratio detections in both 60–140 and 110–200 Å passbands. An unusually high level of chromospheric activity of $\log R'_{HK} = -4.074$ was determined by Gray et al. (2003); a spectral type K2 V is also specified in the latter paper as opposed to G9 V given in the Simbad database. Since the rate of rotation diminishes fairly quickly with age in single stars, so does X-ray luminosity, and open clusters older than α Persei (50 Myr) are usually more quiescent than the youngest ones (IC 2602 and IC 2391). The high degree of chromospheric and extreme ultraviolet activity suggests a very young age, possibly less than 20 Myr. V368 Cep is more powerful in X-rays than an average K-type Pleiades member by a factor of 10, indicating an age less than 100 Myr. Finally, the equivalent width of Li I at $W_{Li} = 0.218$ Å is smaller than the upper limit for the Pleiades by 0.104 Å according to Wichmann et al. (2003), which points at an age similar to the Pleiades or older. However, the lithium surface content is a poor estimator of age for young stars because of the large intrinsic spread of this parameter in stars of the same mass and age.

We are left with the most reliable and frequently used method of age estimation by model isochrones. Using the photometric data from the literature and our own (Table 1), we plot HR diagrams

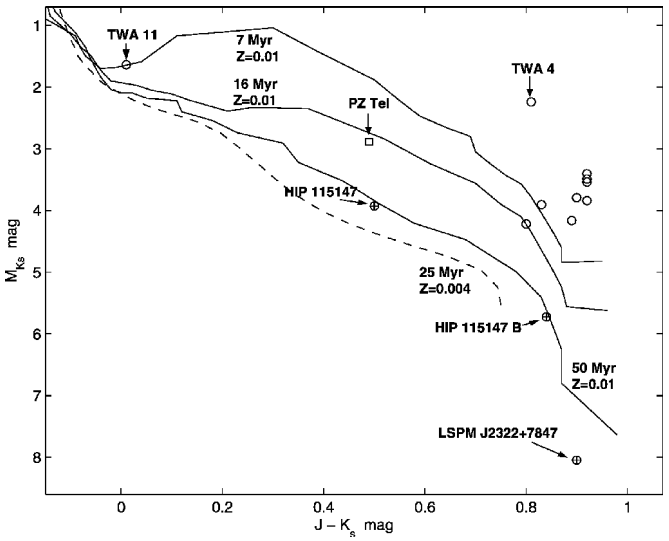

FIG. 1.—Near-infrared HR diagram for HIP 115147 A and B components and for the newly identified CPM companion LSPM J2322+7847 (circles with inscribed crosses). For comparison, the young post–T Tauri star PZ Tel is shown with a square and members of the TWA group of pre–main-sequence stars with open circles. Model isochrones from Siess et al. (2000) for ages 7, 16, and 50 Myr and metal abundance $Z = 0.01$ are drawn with full lines and a 25 Myr isochrone with $Z = 0.004$ from Pietrinferni et al. (2004) is indicated with a dashed line.

in the 2MASS *J* and K_s, and *V* passbands in Figures 1 and 2. For reference, the theoretical isochrones at 7, 16, and 52 Myr are drawn from Siess et al. (2000). According to the data in Nordström et al. (2004) derived from Strömgren *uvbyβ* photometry, the star HIP 115147 has a markedly subsolar metallicity at [Fe/H] = −0.64. This determination has to be taken with caution, because the photometrically derived metallicities are sensitive to the color index m_1 (B. Nordström 2007, private communication), which may be abnormally high for chromospherically active stars (Morale et al. 1996; Favata et al. 1997). A wider range of metal abundances is supplied in the evolution models of Pietrinferni et al. (2004), and we present also a 25 Myr isochrone for $Z = 0.004$ from their

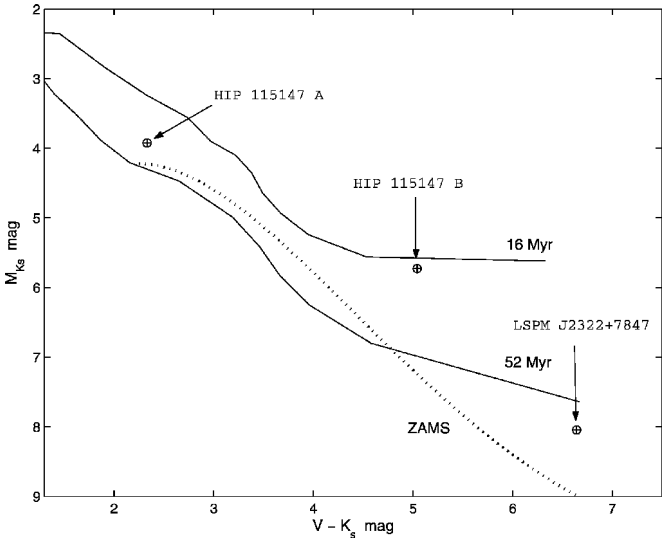

FIG. 2.—M_{Ks} vs. $V - K_s$ HR diagram for HIP 115147 A and B and LSPM J2322+7847 components indicated with circles with inscribed crosses. Model isochrones from Siess et al. (2000) for ages 16 and 52 Myr and metal abundance $Z = 0.01$ are drawn with full lines, and the empirical main sequence of field dwarfs from Henry et al. (2004) is indicated with a thick dotted line.

models in Figure 1 with a dashed line. We find that the Siess et al. 50 Myr isochrone ($Z = 0.01$) provides the best fit for all three alleged comoving components (*crossed circles*), including the secondary M dwarf HIP 115147 B, separated by ~11″ from the primary (Lowrance et al. 2005). This pair is listed in the WDS (Mason et al. 2001) as WDS 23194+7900 (LDS 2035, discovered by Luyten in 1969), at separation 10.8″ and position angle 216°. The relative position did not change significantly between the first AC2000.2 measures taken in 1901 and the latest epoch 2000 in 2MASS (W. Hartkopf & G. Wycoff 2007, private communication), confirming that the inner pair is physical. The small deviation of the faintest component LSPM J2322+7847 from the Siess 50 Myr isochrone appears to arise mostly from a sudden twist of the isochrone at the latest data point corresponding to mass 0.1 $M_{\odot}$. We are not in a position to discuss if this twist has a certain physical meaning, but the overall match is good, and the estimated mass of the star is roughly 0.1 $M_{\odot}$.

The younger isochrones for 16 and 7 Myr from Siess et al. (2000) lie significantly higher in Figure 1 than the matching 50 Myr isochrone. The 25 Myr isochrone from Pietrinferni et al. (2004) at a lower metallicity provides a poor fit to our stars, predicting much bluer colors, but these models may be strongly biased for young ages as was found by Makarov (2006) for solar-type stars in the Alpha Persei open cluster at 52 Myr. The members of the very young TWA association are shown in Figure 1 with open circles. These stars are certainly much younger than HIP 115147 and its companions. They appear to be brighter and redder than the 7 Myr isochrone corresponding to the probable age of this group (see also Makarov et al. 2005), but this deviation may be the result of the near-infrared K and J excess commonly observed in classical T Tauri stars and attributed to a hot inner rim in their dusty accretion disks (Cieza et al. 2005). Since our stars under investigation have no accretion disks and their metal abundance may be lower, we need to find a young star with similar parameters. It was pointed out by Makarov (2007) that a few young stars currently in the solar neighborhood, that traveled from the vicinity of the Ophiuchus star-forming region, share the moderately metal-poor abundance of HIP 115147 as determined from the *uvbyβ* photometry, probably affected by the high degree of chromospheric activity. One of these stars is the extremely active dwarf PZ Tel, a likely member of the β Pic associations estimated to be 12–20 Myr old. This star is indicated with an open square in Figure 1. Its position matches the 16 Myr, $Z = 0.01$ isochrone quite well. PZ Tel is significantly brighter than HIP 115147 in K_s having approximately the same color; thus, the latter star and its companions are probably older than 16 Myr. It is verified in Figure 2 that this difference in M_{Ks} between the two stars is not originating in a K_s-band excess, since both HIP 115147 and LSPM J2322+7847 match best the 52 Myr, $Z = 0.01$ isochrone in a M_{Ks} versus $V - K_s$ diagram as well. The latter star is brighter in K_s than the empirically determined main sequence for field dwarfs from Henry et al. (2004) by 1 mag. If this star were an unrelated old M6 dwarf, its distance would be only 12 pc. Our trigonometric parallax (Table 1) yields a distance 19.4 ± 0.3 pc.

4. CONCLUDING REMARKS

A number of stars with outstanding signs of activity and young age scattered in the solar vicinity can be traced back to their places of origin in, or close to, the OB associations in the Sco-Cen complex (Wichmann & Schmitt 2003). The star HIP 115147 has come from the vicinity of the molecular cloud LDN 1709 in the Ophiuchus star-forming region, flanking the Sco-Cen complex at $l \approx 0$ (Makarov 2007). The closest approach to the estimated center of that association is 10.7 pc, while the separation today is 170 pc. The closest approach 16 Myr ago saw the star flying by at a relative velocity of 10.8 km s^{-1}. If HIP 115147 was born in the Ophiuchus association, its probable age should be 16 Myr, considerably younger than the previous isochrone analysis and the lithium abundance suggest. Because of the high departing velocity, it is more likely that this close fly-by is a chance occurrence.

Finally, we note that the difference in proper motion between HIP 115147 and LSPM J2322+7847, which appears to be statistically significant, may be caused by a systematic error of 5–10 mas yr^{-1} in the NOMAD proper motions for very faint stars. The formal errors specified in NOMAD may be strongly underestimated for this optically dim star, whose position at the mean epoch 1979 is based on Schmidt plates. The proper motion difference, if it is true, implies that the two stars are not gravitationally bound as a truly multiple system. This is commonly observed among very young stars in the solar neighborhood; for example, the common proper motion pair AT Mic and AU Mic (approximately 10 Myr old) are separated by at least 0.23 pc and have proper motions different by ≃7%, but their physical association is not in doubt. At the suggested age (20–50 Myr), the HIP 115147 companions are likely to stay close to each other as a moving group. More accurate absolute proper motions for both companions and spectroscopic radial velocities are required to clarify the dynamical status of the system. The currently available evidence is consistent with LSPM J2322+7847 being one of the youngest, later type stars in the near solar neighborhood.

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